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TRANSPORT LOCOMOTIVE AND WASTE PACKAGE TRANSPORTER DESIGN DEVELOPMENT PLAN

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TRANSPORT LOCOMOTIVE AND WASTE PACKAGE TRANSPORTER DESIGN DEVELOPMENT PLAN

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CHANGE HISTORY

Revision Number	Interim Change No.	Approval Date	Description Of Change
000		06/02/2005	Initial Issue
001		06/08/2005	Section 12.4 added

CONTENTS

TABLES

ACRONYMS

BDBGM	beyond design base ground motion
BSC	Bechtel SAIC Company, LLC
CCTV	closed-circuit television
DBGM	design base ground motion
DDP	design development plan
DOE	Department of Energy
FEA	finite element analysis
FMEA	failure modes and effects analysis
FTA	fault tree analysis
ITS	important to safety
NSDB	Nuclear Safety Design Basis
SSC	structures, systems, and components
WP	waste package

1. PURPOSE

This design development plan (DDP) identifies major milestones for advancing the design of the transport locomotive and waste package (WP) transporter to meet its credited safety functions. This DDP will identify the means of demonstrating that the transport locomotive and WP transporter can be relied upon to perform its safety (ITS) functions identified in the *Nuclear Safety Design Basis for License Application* (NSDB) (BSC 2005 [DIRS171512]). Furthermore, this DDP will define the planned approach and schedule logic ties of design development activities and provides the basis for the subsequent development of performance specifications, test specifications and test procedures.

2. SCOPE

The scope and extent of this DDP is driven by the development requirements defined within the *Transport Locomotive and Waste Package Transporter Gap Analysis Study* (BSC 2005 [DIRS 173925]). This study identifies areas of the transport locomotive and WP transporter where performance acceptance can not be readily sought through the use of commercially available structures, systems and components (SSCs) or use of consensus codes and standards, used in conjunction with a recognized equipment qualification program.

The scope of this DDP is limited to identifying the planned approach and design development activities necessary to advance the design of the transport locomotive and WP transporter to demonstrate that it will meet its credited safety functions. Thereafter, this DDP will form a basis for defining design development and testing requirements within the transport locomotive and WP transporter performance specification. The performance specifications will define the codes, standards, and performance requirements for design, fabrication, and testing of the equipment. Testing activities will be detailed in test specifications and test procedures. Test specifications will detail the requirements for each test, and testing procedures will prescribe how each test is to be performed.

This DDP was prepared by the Emplacement and Retrieval project team and is intended for the sole use of the Engineering department in work regarding the transport locomotive and WP transporter. Yucca Mountain Project personnel from the Emplacement and Retrieval project team should be consulted before use of this DDP for purposed other than those stated herein or use by individuals other than authorized by the Engineering department.

3. PROGRESSIVE APPROACH

Design development requirements and activities identified within this plan are commensurate with the level of design completed for License Application and the associated gap analysis study. Therefore, specific design details, and the selection of specific SSCs may not be known, and all design development requirements may not have been identified within the gap analysis study.

Therefore, a progressive design development approach is presented in this DDP that provides a framework for identifying and detailing design development requirements and activities as the design advances. It is anticipated that as the design matures, to the extent practicable, SSCs that perform ITS functions will be selected based on proven technology and codes and standards that provide assurance they will perform as required without need for extensive design development.

The progressive design development approach includes, as appropriate, the design development activities identified in Section 9. Completion of each design development activity and advancement of the design will determine the need for further design development and completion of additional design development activities.

In addition, the progressive approach maintains flexibility throughout the design process to allow alternative solutions to be explored without compromising design development objectives.

4. DESIGN DEVELOPMENT OBJECTIVES

The primary objectives of this DDP are to demonstrate the reliability of the transport locomotive and WP transporter performance for:

- The rate of WP transporter runaway per trip
- Representative operating conditions
- Off-normal conditions.

5. QUALITY ASSURANCE

This document was prepared in accordance with LP-ENG-014-BSC, *Engineering Studies*. The results of this document are only to be used as the basis for selection of design development activities and are not to be used directly to generate quality products. Therefore, this engineering study is not subject to requirements of the *Quality Assurance Requirements and Description* document (DOE 2004 [DIRS171539]).

6. USE OF COMPUTER SOFTWARE

Computer software used in this study (Microsoft Word 1997) is classified as exempt from procedure LP-SI.11Q-BSC, *Software Management*. All software used to prepare this analysis is listed as "software not subject to this procedure" (LP-SI.11Q-BSC, Section 2.1).

7. FUNCTIONAL DESCRIPTION

The primary function of the transport locomotive is to move the waste package (WP) transporter and other rail-based support equipment utilized by the emplacement and retrieval system, such as the gantry carrier and WP transporter.

The primary function of the WP transporter is to safely transport waste packages between the surface facilities and emplacement transfer docks for both emplacement and retrieval operations.

The transport locomotive provides the motive force for all movements of the waste package transporter. The WP transporter primarily consists of a radiological shielded enclosure (with bedplate) mounted to a railcar.

Within the *Waste Package Transporter Preclosure Safety Analysis* (BSC 2004 [DIRS169554]), a fault tree analysis was performed with two possible alternatives that meet the necessary reliability. Alternative 1 is a single-channel dynamic brake in conjunction with the basic service brake system (BSC 2004 [DIRS169554], Section 6.8.2). Alternative 2 is a single-channel independent brake in conjunction with the basic service brake system (BSC 2004 [DIRS169554], Section 6.8.3).

8. NON STANDARD SSC

Non-standard SSCs are defined as; SSCs not based on commercially available equipment, established industry practices, or consensus codes and standards. The preferred practice is to use, standard components and SSCs whose failure modes, failure effects, and reliability values are documented under similar operating conditions and environments.

The *Transport Locomotive and Waste Package Transporter Gap Analysis Study* (BSC 2005 [DIRS 173925]) identified SSCs that perform ITS functions, and it identified the codes and standards to be used to provide assurance that the will perform as required. In most cases, it was found that ITS functions and requirements could be met using codes, standards, and/or supplements developed specifically for railroad and nuclear applications. The *Transport Locomotive and Waste Package Transporter Gap Analysis Study* (BSC 2005 [DIRS 173925]) identified some design development needs associated with satisfying several operational reliability and design performance safety requirements. These development requirements are detailed in this study.

9. DESIGN DEVELOPMENT ACTIVITES

The following design development activities represent the progressive design development approach to advance the design of the transport locomotive and WP transporter. In turn, as the design advances the need to complete each design development activity, or selectively complete activities, should be determined based on meeting each credited safety function. Design development activities are described in Section 10.

- **Design Activities:**
  - Selection of SSCs
  - Engineering calculations
  - Computer modeling
  - Failure modes and effect analysis (FMEA)
  - Fault tree analysis (FTA)
- **Testing Activities:**
  - Bench testing
  - Prototype testing
  - Integrated testing

Specific design development activities identified in the *Transport Locomotive and Waste Package Transporter Gap Analysis Study* (BSC 2005 [DIRS 173925]) are summarized in Table 2.

Although proven railroad technologies with nuclear adaptations will be used to the extent practicable, several engineering development requirements have been identified. Specifically, the shielded compartment structure needs to be validated; the speed control and braking system component failure rates need to be established; and the functionality of the control, communication, and electrification system need to be demonstrated. Validation of the shielded compartment structure will be demonstrated through calculations, computer modeling, and/or finite element analysis. However, complete demonstration and design optimization will require prototyping.

Prototyping will establish data for the predictable life of components. Data will be established for the drive trains, control components and field mounted devices that are susceptible to premature failure in harsh environments. These data are important for validating equipment performance and recovery operations and for demonstrating equipment maintenance. Testing will simulate accelerated component life cycles and operating environments. Specific systems identified for accelerated life testing include the speed control, braking, and drive system. Specific systems to be monitored for testing with radiation-hardened enclosures include the transport locomotive and WP transporter onboard control systems, onboard sensors, and onboard CCTV system.

In addition, because of the potential for a seismic event to adversely effect the performance of the transport locomotive and WP transporter, it is important to fully understand how the performance of each ITS SSC and safety function is effected. Most notably is the potential for a seismic event to adversely effect the performance of the braking systems that may lead to a runaway.

A seismic event may also excite the vehicle suspension and compromise the WP transporter's ability to negotiate track curves, switches, and other track conditions. Further, a seismic event may adversely effect the structural the WP transporter causing damage to the shielding integrity or causing the WP to impact with the WP transporter structure.

Seismic events may also initiate external event sequences that may lead to a derailment or tipover. These event sequences may include failure of the track ground support or damage to the rail or switches.

To address these concerns and to develop a broad understanding of the potential effects of seismic events on the transport locomotive and WP transporter the following specific design development activities are to be completed:

- Seismic bench testing
- Seismic modeling
- Seismic prototype testing.

10. DESIGN DEVELOPMENT ACTIVITY DESCRIPTION

10.1 SELECTION OF SSCS

To the extent practicable SSCs should be selected based on proven technology that have been used in similar environmental and nuclear operating conditions. Selection of SSCs with proven nuclear pedigrees and well-documented histories may reduce the need for subsequent design development, and SSCs certified to IEEE Std 323-2003, *IEEE Standard for Qualifying Class 1E Equipment for Nuclear Power Generating Stations*, [DIRS 166907] may require little or no physical design development activities. In contrast, the selection of new technologies could require testing to confirm the adequacy of the equipment design under normal, abnormal, design basis event, and post-design basis event conditions, as well as the suitability of the materials and methods of construction.

10.2 ENGINEERING CALCULATIONS

As the design progresses and solutions are evaluated, especially for structural components, engineering calculations could include (at a minimum) the shielded compartment structure. Calculations will be required to confirm that acceptable stress and strain levels are maintained and that maximum deflections are not exceeded. Validation of the WP transporter shielded compartment structure will be demonstrated through calculations, and where necessary, prerequisite to three-dimensional modeling and finite element modeling.

10.3 COMPUTER MODELING

Computerized, three-dimensional simulation modeling should be conducted for design verification during the advancement of the transport locomotive and WP transporter prototype detail design to ensure that the WP transporter will negotiate within site curves. Finite element modeling may be used during design development to provide evidence that design stress levels are not exceeded, especially for the WP transporter shielded compartment structure.

10.3.1 Seismic Modeling

Computer modeling will involve the development of a non-linear dynamic time history finite element model. This model will allow a time-domain interactive analysis of rails, track ground support, and WP transporter coupled to the transport locomotive (stationary and moving) to be performed under a seismic event. Results from the model will be used to improve the performance (by absorbing energy more effectively) of the WP transporter, transport locomotive, and track.

10.4 FAILURE MODES AND EFFECT ANALYSIS

A failure modes and effect analysis (FMEA) should be performed on the transport locomotive and WP transporter according to *IEEE Guide for General Principles of Reliability Analysis of Nuclear Power Generating Station Safety Systems* [DIRS 124964].

The FMEA is usually the first reliability activity performed to provide a better understanding of a design's failure potential. It can be limited to a qualitative assessment, but may include numerical of a failure probability estimates. Important applications of the FMEA include:

- Specifying future tests required to establish whether design margins are adequate relative to specific failure mechanisms identified in the FMEA
- Identifying "safe" versus "unsafe" failures for use in the quantitative evaluation of safety-related reliability
- Identifying critical failures that may dictate the frequency of operational test and maintenance intervals if the failure modes cannot be eliminated from the design.
- Establishing the quality-level for parts (especially electrical parts) needed to meet reliability goals.

- Identifying unacceptable failure mechanisms (failures that could produce unacceptable safety or operational conditions) and the need for design modifications to eliminate them

- Identifying the need for failure detection.

FMEA should be used to identify, by component, all known failure modes, failure mechanisms, effects on the system, method of failure detection, and provisions in the design to compensate for the failures. The analysis should provide established reliability statistics based on failure rates for components used in similar applications and environmental conditions. Reliability data, where available, will be obtained from nuclear facilities with similar quality control requirements. This activity is a prerequisite to performing a detailed fault tree analysis, and it provides the first level of design validation during the conceptual design phase. The FMEA should be periodically updated to reflect changes in design as the design matures.

10.5 FAULT TREE ANALYSIS

A fault tree analysis (FTA) should be performed on the transport locomotive and WP transporter using ANSI/IEEE Std 352-1987 (*IEEE Guide for General Principles of Reliability Analysis of Nuclear Power Generating Station Safety Systems)* [DIRS 124964].

Fault tree analysis should be used to determine the causes and probability of the safety requirements stated within the Nuclear Safety Design Basis for License Application (BSC 2005 [DIRS171512]). The fault tree analysis, performed in conjunction with the results of the FMEA should provide adequate design validation to proceed with prototyping. Important benefits of FTA include:

- Identifying possible system reliability and safety problems during the design phase

- Assessing system reliability and safety during operation

- Improving the understanding of component interaction within a system,

- Identifying components that may need testing or more rigorous quality assurance scrutiny

- Identifying root causes of equipment failures.

10.6 BENCH TESTING OF COMPONENTS

Components that do not have a proven history of operating in radiological environments similar to those expected at Yucca Mountain should be subject to bench testing at a testing facility capable of handling radiation sources and bounding environmental conditions that include radiation, temperature, dust, and moisture.

Because of the magnitude of the radiation source required to simulate the actual operating conditions, it is recommended that only the brake components, electrical components, and control system components be tested in a radiation environment. Because the control system components are relatively small, the radiation tolerance tests could be performed in almost any available hot cell. This test would establish the level of degradation due to radiation in the operating environment.

The following conditions should be considered as applicable during the bench testing cycles:

- Radiation dose rates for emplacement and retrieval equipment are 600.7 rem/hr from the waste package radial surface (BSC 2005 [DIRS 171251], Section 3.2.1.1.1) and 1,290 rem/hr axially from the bottom lid (BSC 2005 [DIRS 171251], Section 3.2.1.1.1).

- The outside temperature environment the equipment could be expected to perform in is 2° F to 116° F (-17° C to 47° C) (BSC 2005 [171251], Section 3.2.5.1).

- Expected outside relative humidity will be 11 to 58 percent (BSC 2005 [171251], Section 3.2.5.2).

- The maximum temperature the equipment could be expected to perform in is 122 ° F (50 ° C) (BSC 2005 [DIRS 171599]), Section 4.8.3.1.1).

- Expected emplacement drift relative humidity will be 3 to 10 percent (BSC 2005 [DIRS 171251]), Section 3.2.5.4).

- The maximum rainfall the equipment could be expected to operate in is 2.15-in per hour (BSC 2005 [171251], Section 3.2.5.6).

Bench testing should be used to validate the following, with consideration of the above mentioned conditions:

- Suitability of materials used in the construction of components and assemblies

- Lubricants used in or on components and assemblies

- The surface-finish of the components and assemblies (natural or painted)

- Evidence that components and assemblies will function properly over their expected operating life.

10.6.1 Seismic Bench Testing

Seismic testing of ITS components and subassemblies will be in accordance to ANSI/IEEE Std 344-1987 [DIRS 159619].

10.7 PROTOTYPE TESTING

The basic approach for prototype testing is to test the critical transport locomotive and WP transporter systems in an environment that simulates the actual operating environment as closely as possible. Prototype testing should be performed at full-scale because some components are unavailability at reduced scale. Full-scale prototyping is recommended because:

- Scalability of the results from a scale model is questionable for enclosure thermal life predictions.

- A scale model approach implies a throwaway model at the conclusion of testing. It is anticipated that the prototype transport locomotive and WP transporter can be used as a production or training unit with minor modifications.

- It is questionable whether scale components are available in all cases.

- The full-scale prototype approach is likely the low-cost plan.

Full-scale testing will also provide the most representative information to the final production equipment. Selection of individual components should consider their influence on test results. Where practicable, components that are identified as ITS should be identical to those to be used in the final production unit.

Prototype testing shall be performed in the following three phases:

- Phase I: Accelerated Testing

- Phase II: Extended Testing

- Phase III Sustained Testing

10.7.1 Accelerated Testing

Accelerated testing should simulate the full life-cycle operations of the transport locomotive and WP transporter for all moving parts (e.g., motors, gearboxes, shafts, and brakes) in a compressed time period. This activity should also include full life-cycle control sequence testing of the control system, including the programmable logic controller, all control instrumentation, switches and sensors, and cabling. The control and instrumentation cabinets should be full life-cycle tested relative to their radiological and environmental resistance capabilities under representative operation conditions (Section 10.6).

Life-cycle operations should be based on all normal movements associated with emplacing an assumed three (3) waste packages per day during a 256-day period per year. This assumption is based on an operating shift of eight (8) hours per day, with three (3) operating shifts per day with each one yielding one emplaced WP. The load handled by the WP transporter will be 200,000 lbs, which includes the maximum weight of a waste package, the weight of a long pallet (BSC 2005 [DIRS171251]), and a 20 percent increase in waste package weight to represent an upper bounding limit. The main access design grade is ± 2.5% (BSC 2005 [DIRS171251], Section 3.1.3.1.2). The linear travel speed of the WP transporter shall be limited to a maximum speed of 8 mph (BSC 2005 [DIRS171251], Section 3.1.3.1.2).

ITS SSCs and prototype extended tests are listed in Table 3 in Appendix B.

10.7.2 Extended Testing

Extended testing should simulate extended life-cycle operations for all moving parts (e.g., motors, gearboxes, shafts, and brakes) of the transport locomotive and WP transporter. This activity should also include full life-cycle control sequence testing of the control system, including the programmable logic controller, all control instrumentation, switches and sensors and cabling. The control and instrumentation cabinets should also be full life-cycle tested relative to radiological and environmental resistance capabilities under representative operating conditions, which are listed in Section 10.7.1.

ITS SSCs and prototype extended test are listed in Table 3 in Appendix B.

10.7.3 Sustained Testing

Sustained testing should simulate the transport locomotive and WP transporter performance under off-normal environment and operational conditions. Off-normal conditions include, for example, high and low temperatures, over travel, collisions, off-set loads, loss of power, communication failure, seizure of moving parts, derailments, and track misalignment. Details that should be considered during sustained testing, and the components to test include:

- All control systems and components, testing should concentrate on, but not be limited to, loss of power, communication, and spurious signals.

- The transport locomotive and WP transporter as whole should be subjected to track misalignment and a derailment simulation.

- Testing should determine that over-speed of the drive system associated with an off-normal event should be prevented by the control system and the braking system, the end-of-travel rail stops, or a combination of these.

ITS SSCs and prototype sustained test are listed in Table 3 in Appendix B.

10.7.4 Seismic Prototype Testing

To the extent practical seismic prototype testing will be done at full-scale to provide fully representative results. Prototyping will include impact and vibration testing of selective and complete assemblies of the Transport locomotive and WP transporter. Prototyping will be based on using a multi-axis shaker table to replicate seismic events. Results from prototyping will be used to verify computer modeling and confirm equipment performance under a seismic event.

10.8 OFF-SITE INTEGRATED TESTING

Off-site integrated testing should be performed to demonstrate interfaces with the transport locomotive, WP transporter, various Waste Packages and pallets, and the subsurface facility. Off-site testing will permit testing to be performed during completion of emplacement drifts. Furthermore, an off-site test facility would also serve as an operator training facility. Integrated testing should be fully representative, to the extent practicable, of real operations with the exception of a radioactive environment.

Due to the mission critical nature of the emplacement system, integrated testing is recommended to support meeting the following goals:

- Demonstrate functionality of the complete system under simulated operational conditions
- Demonstrate practicality of recovery and retrieval plans
- Verify system performance prior to delivery to site
- Provide preparation for operational readiness review
- Permit early hands-on involvement of regulatory agencies
- Permit early operator training capabilities
- Provide early feedback for necessary modifications or design enhancements.

10.9 OPERATIONAL READINESS REVIEW

Although operational readiness review is beyond the scope of this DDP, it is mentioned here for completeness. An operational readiness review should follow off-site integrated testing and highlights the final milestone in demonstrating the performance of production ITS SSCs.

11. INFORMATION COLLECTION AND INSPECTION REQUIREMENTS

The primary objectives of this DDP are to demonstrate the reliability of ITS transport locomotive and WP transporter functions under representative operational conditions. Although, individual components will be selected based on previous use in similar nuclear applications, it is unlikely that they have been used within the same configuration or for exactly the same application, and therefore component failure or excessive wear may be influenced by unknown interactions. Therefore, to evaluate component failures that influence reliability, it is essential that information be collected during each stage of the component life (i.e., manufacture, construction and operation). This information may then be used to ensure that a root cause analysis can be performed on the components that do not meet their design and performance objectives.

Typical data collection requirements for ITS SSCs are listed in Table 4 in Appendix C.

11.1 BASELINE DATA

To assess wear and failure modes of ITS components, it is essential that detailed baseline data be obtained. The data, at a minimum, should include a physical inspection of each component before and after installation to identify any defects and anomalies. All noted defects and anomalies must be addressed prior to testing. Typical data should include weights, important dimensions, and surface finishes.

11.2 ACCELERATED TEST DATA

Throughout life-cycle prototype testing, sufficient instrumentation should be provided to monitor the performance of ITS components. Instrumentation should provide real-time monitoring and feedback on important measurements and operating parameters. Measurements, as a minimum, should include:

- The effects of temperature on components and fabrications caused by environmental temperatures coupled with the heat developed by components during operation (e.g., motors, gearboxes, bearings, speed control equipment, sensors, switches, cables, and relays).

- The ventilation system for the control cabinets should be monitored to ensure acceptable temperatures for the electronic components (e.g., switches, relays, and cables).

- The effects of the design loads on all load bearing components and fabrications should be monitored for stress and strain levels, physical deflections, and reductions in surface finish on drive components (e.g., shafts, and bearings) caused by wear.

- Motor power requirements should be recorded during the operations of vehicle and bedplate movements.

- The drive system components (e.g., motors, gearboxes, and bearings) should be monitored for vibration and sound during operating cycles.

- The speed control and braking systems for the transport locomotive, WP transporter, and bedplate motion should be monitored under all conditions.

Instrumentation, where practicable, should include vision and audible feedback.

During accelerated testing, components will be inspected and maintained (e.g., adjustments and lubrication) as part of a scheduled maintenance regime based on vendor data. Where practicable, supplement vendor data with predictive maintenance and condition-monitoring techniques.

11.3 EXTENDED TEST DATA

Data requirements for extended testing are similar to those for accelerated testing, with the exception that a detailed inspection of each ITS component needs to be performed prior to testing to determine component wear and life expectancy.

11.4 SUSTAINED TEST DATA

Data requirements for sustained testing are similar to those for accelerated testing, with the exception that a detailed inspection of each ITS component needs to be performed after each sustained test evolution to monitor for evidence of progressive fatigue, cumulative fatigue, and component failure.

11.4.1 Seismic Test Data

Seismic prototype testing should be conducted during sustained testing. Instrumentation of equipment should provide real-time feedback and should include as a minimum stress and strain measurements of all ITS SSCs (e.g. braking system, shielded compartment etc.) and supporting SSCs (e.g. support brackets, railcar undercarriage etc.). Throughout testing components should be monitored for evidence of defects, flaws or failures.

11.5 OFF-SITE INTEGRATED TEST DATA

After prototype testing of individual components, it will be necessary to demonstrate the overall functionality of the complete system. This phase of testing is referred to as integrated testing. To the extent practicable, integrated testing will be used to demonstrate the performance of the complete system under simulated operational conditions. Prior to off-site integrated testing, used equipment should be refurbished or replaced to new condition. Data collection for integrated testing should be fully representative of anticipated operating conditions.

12. EXPECTED RESULTS AND SUCCESS CRITERIA

The expected results and success criteria, based on satisfying the ITS performance requirements specified in *Nuclear Safety Design Bases for License Application* (BSC 2005 [DIRS171512]), are outlined in this section. Deviations from expectations should be subjected to close inspection or further evaluation. If necessary, additional testing may be required to verify the data or to provide additional information for root cause analyses.

12.1 ACCELERATED TESTING

At the completion of accelerated testing, all ITS reliability requirements specified in *Nuclear Safety Design Bases for License Application* (BSC 2005 [DIRS 171512]) should have been met, as specified in Table 1.

To achieve these reliability requirements, it is expected that the transport locomotive and WP transporter will not require any unplanned maintenance. Where practicable, components should be selected or designed to support an operational life of 2 years, (BSC 2005 [DIRS171512], Section 3.2.1.3.1) without breakdown or the need for replacement. Failure of ITS components within this period, results that are not consistent with vendor data, and bench testing should be closely evaluated to determine root causes for any failures or problems found.

Table 1: Reliability Requirements

Performance Requirements	Target Reliability
WP Transporter runaway per transfer	8.3×10^{-9} per trip

Source: BSC 2005 [DIRS171512].

12.2 EXTENDED TESTING

Extended testing should provide added confidence that ITS reliability requirements can be meet with a degree or margin over an extended operational life. Therefore, successful extended testing should conclude with results that further support accelerated testing. Extended testing should provide a basis for the timing of planned maintenance outages during which components and assemblies would be inspected and maintained. Maintenance outages should be completed at regular intervals with minimal impact on operations. During these outages the transport locomotive and/or WP transporter would be transferred to the Heavy Equipment Maintenance Facility where a planned inspection and maintenance program would be completed prior to returning into service.

12.3 SUSTAINED TESTING

Sustained testing should provide added confidence that ITS reliability requirements can be meet with a degree or margin under off-normal conditions. Therefore, successful sustained testing should conclude with results that further support accelerated and extended testing. Sustained testing would highlight potentially weak areas, or demonstrate areas of unacceptable wear and identify signs of fatigue. This should add confidence to the determined frequency of planned maintenance outages.

12.3.1 Seismic Testing

Seismic prototype testing should demonstrate that the WP transporter coupled to the transport locomotive can performance its ITS safety functions during and after a DBGM-2 seismic event, and can maintain its ITS safety functions during a BDBGM seismic event. Moreover, prototyping should demonstrate overall operability of the system to predict the behavior of the WP transporter and its interactions with the track and track ground support systems.

12.4 OFFSITE INTEGRATED TESTING

Off-site integrated testing will provide assurance the system will perform all required safety functions and that interactions with other equipment interfaces including recovery systems are as specified. During this testing, improvements may be highlighted that will be incorporated prior to delivery and installation of the equipment on site.

13. LOGIC TIES TO DESIGN ENGINEERING, PROCUREMENT, AND CONSTRUCTION

Logic ties to Design Engineering, Procurement, and Construction organizations are listed in Table 5-1 in Appendix D. These ties are based on major design development milestones for the transport locomotive and WP transporter.

14. REFERENCES

14.1 DOCUMENTS CITED

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14.2 CODES AND STANDARDS

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124964 ANSI/IEEE Std 352-1987. *IEEE Guide for General Principles of Reliability Analysis of Nuclear Power Generating Station Protection Systems.* New York, New York: The Institute of Electrical and Electronics Engineers. TIC: 246332.

166907 IEEE Std 323-2003. 2004. *IEEE Standard for Qualifying Class 1E Equipment for Nuclear Power Generating Stations.* New York, New York: Institute of Electrical and Electronics Engineers. TIC: 255697.

APPENDIX A – ITS SSCS – DESIGN DEVELOPMENT ACTIVITIES

Table 2: Design Development Activities for Structures, Systems, acd Components Important to Safety

REF	NSDB REQUIREMENT	APPLICABLE SSCs	DESIGN DEVELOPMENT NEEDS				
			REQUIRED ANALYSIS	REQUIRED DRAWINGS	REQUIRED CALCULATIONS	REQUIRED MODELING	REQUIRED TESTING
15.1	*While on the surface, the WP transporter shall be designed to function in extreme straight wind (90 mph).*	Suspension, Brakes, SSC protective equipment	Wind load analysis	General Assembly		Wind simulation w/ track stability Brake simulation with wind applied	Wind tunnel test SSC protective equipment Bench environmental testing
15.2	*The rate of a WP Transporter runaway shall be less than 8.3×10^{-9} runaways per trip.*	Braking system with controls	FMEA FTA	General Assembly		Braking performance simulation	Individual SSC bench testing followed by full scale prototype
15.3	*The WP Transporter (together with the locomotive and coupler) shall be designed to prevent runaway of the WP Transporter for loading conditions associated with a DBGM-2 seismic event. In addition, an analysis shall demonstrate that the WP Transporter (together with the locomotive and coupler) has sufficient seismic design margin to ensure that a "no runaway" safety function is maintained for loading conditions associated with a BDBGM seismic event.*	Speed control / braking system with controls couplers	Seismic analysis on site, substructure, rails, transport locomotive, and WP transporter			Seismic simulation on transport locomotive and WP transporter	Individual SSC seismic bench testing followed by full scale prototype seismic test
15.4	*The WP Transporter shall be designed for loading conditions associated with a DBGM-1 level seismic event and demonstrate sufficient margin to a 'shielding integrity remains intact' safety function.*	Shielded compartment, doors, hinges, and locking mechanisms	FEA structural analysis on shielded compart-ment			Seismic simulation on WP transporter and WP	Individual SSC full scale prototype seismic test Radiation shielding test

APPENDIX B – ITS SSCS PROTOTYPE TESTING

Table 3: Prototype Testing for Structures, Systems, and Components Important to Safety

ITS SSCs Prototype Testing	
ITS SSCs	**Test**
WP transporter shielded compartment: Shielded compartment structural frame Hinges Shielded compartment doors Shield door locking mechanisms	Accelerated & Extended Testing: Life cycle load testing Life cycle control sequence testing Seismic test Sustained Testing: Radiation test
Braking system with controls: Transport locomotive control system Speed control system Speed sensor Dynamic brake (alternative 1 only) Transport locomotive brake control system Pneumatic tread brake system Disc brake system (alternative 2 only) Transport locomotive coupler WP transporter control system WP transporter brake control system Pneumatic tread brake system Disc brake system (alternative 2 only) WP transporter coupler	Accelerated & Extended Testing: Life cycle brake application testing (including curves) Life cycle control sequence testing Seismic test Sustained Testing: Spurious signals Communications failure Power failure Failed and seized components Radiation
Suspension	Accelerated & Extended Testing: Wind load and effect testing Seismic test Sustained Testing: Wind load and effect testing
SSC Exterior Protective Equipment	Accelerated & Extended Testing: Environmental testing (Dust, rain, etc.) Seismic test Sustained Testing: Radiation Temperature Humidity

APPENDIX C – ITS SSCS DATA COLLECTION

Table 4: Data Collection for Structures, Systems, and Components Important to Safety

ITS SSCs Data Collection	
ITS SSC	**Data Collection**
WP transporter shielded compartment: Shielded compartment structural frame Hinges Shielded compartment doors Shield door locking mechanisms	Load measurements Beam defections Stress and strain measurements Non-destructive testing of welds
Braking system with controls: Transport locomotive control system Speed control system Speed sensor Dynamic brake (alternative 1 only) Transport locomotive brake control system Pneumatic tread brake system Disc brake system (alternative 2 only) Transport locomotive coupler WP transporter control system WP transporter brake control system Pneumatic tread brake system Disc brake system (alternative 2 only) WP transporter coupler	Temperature (cabinets, lubricants, and bearings) Radiation (seals, lubricants) Speed (shafts, motors) Current, voltage (motors) Radiation (cable insulation, electronics, switches) Wear (bearings, shafts, and brakes) Air pressure (brake lines, reservoir) Braking force (pad wear) Surface finish (shafts, hooks) Sound (gearbox, motors, bearings)
Suspension	Suspension deflection
SSC Exterior Protective Equipment	Temperature (cabinets) Radiation (cabinets) Humidity (cabinets) Air pressure (brake lines, reservoir)

APPENDIX D – TRANSPORT LOCOMOTIVE AND WASTE PACKAGE TRANSPORTER DDP MILESTONES

Table 5: Design Development Milesstones for the Transport Locomotive and Waste Package Transporter

Transport Locomotive and Waste Package Transporter Design Development Milestones						
Design Development Milestone	**Description**	**Project Phase**	**P3 Logic Tie Activity ID**	**P3 Logic Tie Activity Description**	**Target Start**	**Target Finish**
Fault mode and effect Analysis	Detailed FMEA of prototypical design	Procurement - Design Engineering Subcontract	RP6K2100	Prototype Design (Transport Locomotive & WP Transporter)	Oct 2006	July 2007
Fault tree analysis	Detailed fault tree analysis of prototypical design	Procurement - Design Engineering Subcontract	RP6K2100	Prototype Design (Transport Locomotive & WP Transporter)	Oct 2006	July 2007
Test Specifications and Test Procedures	Test specifications and test procedures for bench testing and prototyping	Procurement - Design Engineering Subcontract	RP6K2100	Prototype Design (Transport Locomotive & WP Transporter)	Oct 2006	July 2007
Bench testing	Bench testing of ITS components	Procurement – Design Build Subcontract	RP6K3010	Prototype Fabrication of Transport Locomotive & WP Transporter	Oct 2007	July 2007
Prototyping – Phase I	Accelerated testing	Procurement – Design Build Subcontract	RP6K3015	Prototype Testing (Transport Locomotive & WP Transporter)	Sep 2008	Mar 2009
Prototyping – Phase II	Extended testing	Procurement – Design Build Subcontract	RP6K3015	Prototype Testing (Transport Locomotive & WP Transporter)	Sep 2008	Mar 2009
Prototyping – Phase III	Sustained testing	Procurement – Design Build Subcontract	RP6K3015	Prototype Testing (Transport Locomotive & WP Transporter)	Sep 2008	Mar 2009

Integrated Testing	Off-site integrated testing	Procurement – Design Build Subcontract	RP6K3030	Offsite Integrated Testing	Aug 2009	Apr 2010